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(54) ATOMISATION OF LIQUIDS

(71) We, IMPERIAL CHEMICAL INDUSTRIES LIMITED, Imperial Chemical House, Millbank, London SW1P 3JF, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the atomisation and electrodeposition of liquids. It has particular application to the spraying of crops with pesticidal compositions.

When a liquid is displaced from the locality of an electrically conducting surface at a voltage above or below earth potential the liquid may upon emerging into free space carry a net electrical charge resulting from an exchange of electrical charges with the source of the electrical potential. This technique can be used to atomise the displaced liquid since the net electric charge in the liquid as the liquid emerges into free space from the locality of the conducting surface counteracts the surface tension forces of the liquid. The amount of electrical charge in the emerging liquid droplets after atomisation is, in part, dependent upon the strength of the electric field at the conducting surface.

There are known devices, particularly used for electrostatic paint spraying, wherein the field strength at the conducting surface has been maximised by (i) sharpening an "edge" of the conducting surface, which may, for example, be a rotating sharp-edged disc, adjacent which edge paint is constrained to emerge; (ii) raising the electrical potential of the conducting surface to a high value, generally of the order of 60–100 Kv; and (iii) ensuring that the spray-target, which is earthed and is thus an earth boundary of the electrostatic field that exists between the conducting surface and the target surface, is sufficiently close to maintain a high field strength at the conducting surface adjacent which the liquid emerges. The conducting surface and the target surface define the main boundaries of the electric field.

A salient feature of such known devices is that the combination of high voltage and sharp-edged conducting surfaces causes breakdown of the surrounding air (by the phenomenon known as corona discharge). The effect of this is that not all of the current supplied to the conducting surface is used to charge the liquid. Thus, corona discharge results in unnecessary current loss and greatly increases the current drawn from the source of high electrical potential. This has disadvantages. One serious disadvantage is that the power required of the high electrical potential source is too high to be met easily by portable energy sources e.g. torch batteries.

Surprisingly, we have now found that if an electrode, hereinafter referred to as a field-intensifying electrode, is in close proximity to the conducting surface it enables a sufficiently high field strength to be created at the conducting surface using a relatively low voltage, of the order of 1–20 KV, to charge the droplets. Thus a high degree density for example, of the order of 10^{-2} coulombs/kilogram may be placed upon the liquid. This gives rise to a high charge-utilisation efficiency which in turn enables low power sources, such as piezoelectric crystals, torch batteries or solar cells to be utilised as a charge transfer device, and to give rise to electrostatic atomisation of the liquid.

Such atomisation requires no mechanical assistance such as an air blast or rotating disc. The combined field due to the voltage on the conducting surface plus the space charge of the atomised liquid itself then enables the droplets to be targeted toward an earthed object, or to form an airborne (aerosol) cloud.

The field-intensifying electrode may be considered to be a "dummy target" since it strongly influences the field in the region

of liquid atomisation. But, unlike an actual target, it is placed close to the conducting surface thus strengthening the field. Surprisingly, we have found that the electrode may easily be placed so that it does not itself become a target for the atomised spray.

The reason for this is not fully understood, but observation shows that, provided the liquid's physical characteristics (e.g. resistivity, viscosity) and flow rate are such as to produce threads or ligaments (electrostatically) or liquid projecting about 1 cm or more from the conducting surface, the atomisation will take place in that part of the field where the combined forces of inertia, gravity field, and electrostatic field are directed away from the electrode.

It has been found possible to cause some inpingement of the spray on to the field-intesifying electrode by placing it downstream of the atomising tip of the ligament. In this case it has been noticed that, with relatively small amounts of impinging liquid, provided the surface of the electrode is sufficiently conducting, and earthed, the impinging particles give up their charge and take up an opposite charge by induction in the electric field. This causes them to re-atomise and not to be retained on the electrode.

Accordingly, the invention provides a process of spraying pesticides which comprises supplying a liquid pesticidal composition to an electrically conducting or semi-conducting surface adjacent a field intensifying electrode, the electrode being at such a potential and so sited relative to the surface that an atomising field strength is created at the surface so that the liquid is atomised at least preponderantly by electrostatic forces substantially without corona discharge to form electrically charged particles which are projected away from the electrode.

This invention also includes electrostatic spraying apparatus suitable for use in the process of the invention, which comprises a spray-head having a conducting or semi-conducting surface; means for electrically charging the spray-head surface to a potential or the order of 1–20 kilovolts; means for delivering spray liquid to the surface; a field-intensifying electrode mounted adjacent to the surface; and means for connecting the field intensifying electrode to earth; the electrode being so sited relative to the surface that when the surface is charged, the electrostatic field thereat causes liquid thereon to atomise without substantial corona discharge to form electrically charged particles which are projected past the electrode.

Preferably the field-intensifying electrode and any spray target are both at earth potential.

By the term "conducting" we mean having a resistivity of the order of 1 ohm cm or less, and by "semi-conducting" we mean having a resistivity value of between 1 and about 10^{12} ohm cm. By "insulating material" is meant material having a resistivity of more than 10^{12} ohm cm.

The conducting or semi-conducting surface adjacent which the liquid atomises may have various shapes. It will often be the end of a spray conduit, preferably a conduit of capillary size, for example, a nozzle aperture, through which in operation the liquid spray emerges.

The conducting surface may also comprise the edges of two concentric tubes which edges define an annular aperture through which liquid emerges. The edges of the tubes may be serrated or butted. Alternatively, the conducting surface may comprise two edges defining a slot, preferably of capillary width. The slot may be of rectangular or other form. Atomisation may be effected from the flat surface of a solid conductor or semi-conductor to which liquid has been supplied.

The geometric shape of the field-intensifying electrode in general follows the shape of the conducting or semi-conducting surface. Where the surface is defined by a nozzle the electrode may take an annular form with the electrode encircling the nozzle.

The field-intensifying electrode is generally sited as close as possible to the conducting surface without corona discharge occurring between them. For example with 20 KV on the conducting surface the electrode is preferably sited not less, and not much more than, about 2 cm away from it. The electrode may be sited either level with, in front of, or behind the conducting surface from which the liquid atomises.

In a preferred form of the invention the field-intensifying electrode has an insulating surface. For example, it may be a thin wire embedded in a body or sheath formed of a plastics material. This enables the distance between the electrode and the conducting surface to be very much smaller than would be obtainable with "air-gap" insulation only. This results in an enhanced field strength in the locality of the conducting surface.

It is preferred that the electrode be adjustably mounted on the apparatus of the invention so that the spatial relationship between the electrode and the surface can easily be varied.

We have found that the position and the geometric shape of the field-intensifying electrode control the angle of the stream of droplets emerging into free space. When

the electrode is behind the emerging spray the angle of the stream is increased, and when it is in front of the emerging spray the angle is decreased.

In addition, we have found that the average size of the atomised droplets in general may be controlled by the position of the field-intensifying electrode in relation to the conducting surface. For example, for a given flow rate of liquid, bringing the electrode closer to the conducting surface results in the droplets generally being of a smaller average size.

By controlling the position of the electrode a selected size of droplets may be produced suitable for a particular use. For example, large numbers of small particles (e.g. 20–30μ) of an insecticide may be preferred for maximum coverage of a target, whereas for a herbicide larger droplets less prone to wind drift may be required. This selected droplet size can be maintained notwithstanding the movement of the target relative to the conducting surface because the field strength created by the electrode outweighs that produced by the target.

We have found also that for a given voltage and a fixed electrode position the droplet size of a given liquid is related to throughput.

The apparatus may also comprise one or more additional field-intensifying electrodes to further influence the spray pattern. For example, if in a system comprising a conducting nozzle and an earthed circular electrode around it, a second earthed circular electrode is placed outside the first, this will broaden the spray swath; and conversely a second earthed circular electrode of smaller cross-sectional area disposed downstream of the nozzle will narrow the spray swath.

We have found that how well a liquid is atomised depends on the potential on the surface, the position of the field-intensifying electrode, the liquid throughput, and the nature of the liquid. For practical purposes we have found that highly non-polar liquids, e.g. pure hydrocarbon solvents, and highly polar liquids, such as water, do not atomise so well.

Atomisation of a liquid effected by the process or apparatus according to the invention requires no mechanical assistance such as a forced air blast or rotating disc. However, once the liquid has been atomised and has passed out of the atomising field a forced air blast may be used to project the atomised droplets over greater distances to a target, thus for example assisting penetration through foliage. The use of a rotating disc as the surface from which liquid is atomised is within the scope of the present invention provided conditions are such that atomisation is caused at least preponderantly by electrostatic forces.

Where liquid is atomised from a surface which is rotatable to assist atomisation of the liquid, atomisation and spraying trajectories are influenced by both inertial and electrostatic forces. Surprisingly, it is found that both of these forces combine favourably even at potential differences of the order of 10 KV or less, to produce fine atomisation. For example, with air-gap insulation only between the field intensifying electrode and the conducting surface at a potential difference of about 20 KV, using a 3-inch diameter disc rotating at 1,500 revolutions per minute as the conducting surface, a droplet mean diameter of the order of 20–30μ has been observed at a flow rate of 1·0 cc per second.

Under certain conditions, for example, if the throughput of liquid is high enough, a pwerful space-charge may be created between the spray nozzle and its target due to the presence of large numbers of charged particles. The space-charge may be sufficiently large to repel very fine charged particles emerging from the nozzle, giving them an appreciable component of velocity in a direction normal to, or even opposite to, the nozzle-target direction. We have termed this effect "back-spray".

We have discovered that a suitably placed deflector electrode at a high potential may prevent this "back-spray".

Accordingly, in yet a further embodiment of the invention there is provided spraying apparatus comprising spraying apparatus according to the invention as hereinbefore defined and further comprising a deflector electrode capable of receiving a high potential and so sited between the field-intensifying electrode and the body of the apparatus that "back-spray" is prevented.

The deflector electrode may be formed of a metal such as steel or aluminium. When the field adjusting member is of an annular form the deflector electrode may take the form of a co-axial ring of slightly greater diameter than that of the field-intensifying electrode, and disposed slightly behind it. The deflector electrode may be mounted on an insulating support so as to be fixed in space and retain charge. A disc formed of a plastics material such as "Perspex" may be used for this purpose.

The voltage on the deflector electrode may be set by either:

(a) a tapping from the high-voltage source used to charge the conducting surface of the spraying apparatus, either directly, or via a potential divider of very high resistance to prevent unwanted power dissipation; or,

(b) a separate source of high voltage, which could be of lower power rating since

the deflector electrode is not essentially an active device because no power is consumed in its operation.

Typically, when the conducting surface has a voltage of 20 KV, a suitable voltage for the deflector electrode would be 15–20 KV. Also, typically, the total resistance of a suitable potential divider would be of the order of 10^{11} ohms. Such a resistance can be realised by use of a semi-insulating material of about 2 cm length and of 1 square cm cross-section (any geometric shape) having electrodes placed at the ends of the material, and together with a tapping electrode suitably set between the ends to obtain the potential division required. Strips of wood, cardboard, and rubber-like materials may be used.

In yet a further embodiment of the invention there is provided spraying apparatus which comprises two or more spraying devices according to the invention mounted on a boom. The boom may be hand-held, or mounted on, or comprising part of, a tractor or aircraft. Such devices according to the invention are of particular use in multi-row crop spraying, and for the spraying of crops and weeds by tractor or aircraft mounted sprayer.

Some embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is an elevational view, schematically illusrating the principal components, of a preferred electrostatic spray gun according to the invention;

Figure 2 is a cross-sectional view of the gun nozzle as shown in Figure 1;

Figure 3 is an underside view of the gun nozzle of Figure 2;

Figure 4 is an electrical circuit diagram of the spray gun of Figure 1;

Figure 5 is an elevational view, part cut away, schematically illustrating the principal components of a spray pistol according to the invention;

Figure 6 is an electrical circuit diagram of the spray pistol of Figure 5;

Figure 7 is a cross-section view of a gun nozzle comprising two concentric tubes for a spray gun according to the invention;

Figure 8 is an underside view of the gun nozzle of Figure 7;

Figure 9 is a cross-sectional view of a gun nozzle comprising a solid conducting block for a spray gun according to the invention;

Figure 10 shows the spray gun of Figure 1 further comprising a deflector electrode;

Figure 11 is a cross-sectional view of the gun nozzle shown in Figure 10;

Figure 12 is a perspective view of a head of a spraying apparatus according to the invention comprising a linear slit arrangement;

Figure 13 is a cross-sectional view on the line I–I of Figure 10!

Figure 14 is an underside view in part of the apparatus of Figure 10.

Referring to Figure 1, the electrostatic spray gun comprises a hollow tube 1 formed of a plastics material and providing a firm holding support for other parts of the gun. Within the tube 1 is a bank of sixteen 1½ volt batteries 2 which acts as the electrical energy source. Attached to the side of the tube 1 is a Brandenburg 223P (0–20 KV, 200 microamp) high voltage module 3 connected to the batteries 2 and to a "ON-OFF" switch 4, and providing a source of high electrical potential. The tube 1 at its forward end has an integral, internally screw-threaded eye 5 adapted to receive a bottle 6 containing liquid to be sprayed. The eye 5 at its lower part holds the upper part of a tubular distributor 7 formed of an insulating plastics material and supporting in its lower end a disc 8 (Figure 2) of the same material. Now, referring more specifically to Figure 2, projecting through the disc 8 are eight metal capillary tubes 9 which form the spray nozzle assembly. The capillary tubes 9 are each soldered to a bare-metal wire 10 which in turn is connected to the high potential terminal of the module 3 via a high potential cable 11.

Encircling the distributor 7 is an inverted dish 12 formed of an insulating plastics material. Supported in the lip of the dish 12 is a metal field-intensifying ring member 13 electrically connected to earth by an earth lead 14. The dish 12 may be moved up and down the distributor 7 but fits sufficiently closely thereon to maintain by frictional engagement any position selected.

To assemble the spray gun for use, the bottle 6, containing liquid to be sprayed, is screwed into the eye 5 while the spray gun is inverted from the position shown in Figure 1. Inverting the spray gun back to the position shown in Figure 1 allows the liquid to enter the distributor 7 and to drip out of the capillary tubes 9 under gravity flow.

In operation to spray liquid, the spray gun is held by hand at a suitable position along the length of the tube 1.

On turning switch 4 to its "ON" position, the capillary tubes 9 become electrically charged to the same polarity and potential as the output generated by the module 3. This results in the liquid emerging from the tubes in an atomised and electrostatically charged form when the gun is inverted to the spraying position.

When the field-intensifying electrode 13 is earthed, via earth lead 14, the electro-

static field at and around the capillary tubes 9 improves both the atomisation and the spray pattern even when the potential on the spray nozzle assembly is at only, say, 10 to 15 kilovolts (either positive or negative polarity with respect to the field adjusting member 13.) Furthermore, due to the close proximity of the electrode 13 to the spray nozzle assembly, the current drawn from the source of high potential 3 is mainly that which arises from an exchange of charge between the capillary tubes 9 and the liquid being sprayed, and is thus extremely small.

Typically, the charge density of the atomised liquid is 1×10^{-3} coulomb per litre. Thus, at a liquid flow rate of, say 1×10^{-3} litre per second the current drawn from the module 3 is only 1×10^{-6} ampere, indicating an output power of only 1×10^{-3} watt when the high potential is 1×10^{3} volts. At this low power, the useful life of the batteries 2 used to energise the module 3 may be hundreds of hours.

To maintain the field-intensifying electrode 13 at low or zero potential, the earth lead 14 must contact actual ground or some other low voltage, high capacitance, body. For portable use of the spray gun shown in Figure 1, it is sufficient to trail the earth lead 14 so that it touches or occasionally touches the ground. The spray gun may be used for short periods of time without the earth lead 14 being connected to earth, without noticeably affecting the spray characteristics. Even when the earth lead 14 is not electrically earthed at all the spray gun will continue to spray electrostatically, albeit with a deterioration in performance.

By varying the position of the dish 12 along the length of the distributor 7 the position of the electrode 13 may be adjusted with respect to the fixed position of the capillary tubes 9 so as to achieve the best spray characteristic in accordance with the potential difference between the electrode 13 and the capillary tubes 9, and other variables such as the electrical resistivity of the liquid.

The specific embodiment described hereinabove was tested with various liquids and various target surfaces.

In a first test the spray gun was used to spray an acrylic paint solution (resistivity approximately 1×10^{7} ohm centimetre) onto a flat surface and onto a section of metal tubing. In both cases, atomisation was found to be satisfactory with the well-known electrostatic "wrap-round" effect being clearly demonstrated.

In a second test conducted outdoors a liquid insecticide formulation (resistivity approximately 5×10^{8} ohm cm) was electrostatically sprayed against a set of earthed vertically placed metal tubes, each of 1 inch diameter, placed in a downward line at distances of 1 to 15 metres from the spray gun; the liquid being atomised at a height of about 1 metre above the ground. A comparative test was conducted using a commercially available mechanical atomising device used for agricultural spraying wherein atomisation is produced from an uncharged spinning disc.

It was found that the droplets from the electrostatic spray gun were deposited more uniformly on all of the metal tubes than those from the mechanical atomiser. The electrostatic spray gun again clearly demonstrated a significant "wrap-round" effect.

In a third test, the second test was repeated but with the 223P; 0–20 KV; 200 microamp module 3 (ex. Brandenburg Ltd.) being replaced with a 11KV unit having no regulation or feedback control and being capable of delivering an output of only 1 microamp at about 11 KV.

In this test the liquid was electrostatically atomised and sprayed satisfactorily.

The apparatus shown in Figure 1 may be used to produce an electrostatically charged aerosol, i.e. a cloud of droplets having a mean droplet size of less than 50 microns in diameter and generally in the range of 1–10 microns. The apparatus of Figure 1 having capillary tubes with an internal diameter of 0·1 mm, and using a liquid having a resistivity approximately 5×10^{8} ohm metre at a total flow rate of 0·05 cc/second per eight capillary tubes produces such an aerosol cloud.

A further embodiment of the invention is the electrostatic spray hand pistol shown in Figure 5. In this embodiment the source of high potential comprises lead zirconate crystals which generate the potential means of the well-known "piezoelectric effect".

The hand pistol shown in Figure 5 comprises a pistol-shaped casing 21 formed of an insulating plastics material, and a metal trigger 22 (shown in Figure 5 in a released position). The upper part of the trigger 22 is shaped to form a cam 23.

Within the handle of the pistol are two lead zirconate crystals 24 (type PZT4, manufactured by Vernitron Ltd., Southampton, England) having a centre tap connection 25. The crystals 24 each have an upper face 26 which in operation is acted upon by the cam 23.

Fitted to the end of the nozzle of the pistol is a distributor 27 formed of an insulating plastics material which holds at its end adjacent the nozzle a disc 28 formed of the same material. Protruding through the disc 28 into the distributor 27 is a feed tube 29, having a tap 30, which in connected to a feed bottle 31 which holds the liquid to be sprayed.

The distributor 27 at its other end has

a disc 32 formed of an insulating plastics material through which protrude eight metal capillary tubes 33 which form the spray assembly. The capillary tubes 33 are each soldered to a bare-metal wire 34 which in turn is connected to the centre tap connection 25 via a high potential cable 35 provided within the barrel of the pistol.

Encircling the distributor 27 is a cylindrical support 36 formed of an insulating plastics material. The support 36 may be moved along the length of the distributor 27 but fits sufficiently closely thereon to maintain by frictional engagement any position selected. Embedded in the support 36 is a metal field-intensifying ring member 37 which is electrically connected to the trigger by an earth lead 38.

In operation to spray liquid, the tap 30 is turned on. This allows liquid to flow under gravity from the feed bottle 31 along the feed tube 29 into the distributor 27 and to emerge dropwise out of the capillary tubes 33.

On squeezing the trigger, the cam 23 acts on the faces 26. This action compresses the crystals 24 and results in the generation of a potential difference, which is transmitted via the cable 35 to the capillary tubes 33. This results in the liquid emerging from the tubes 33 in an atomised and electrostatically charged form.

When the field-intensifying electrode 37 is earthed, via earth lead 38, trigger, and operator, the electrostatic field at and around the capillary tubes 33 improves both the atomisation and the spray pattern.

By varying the position of the support 36 along the length of the distributor 27 the position of the electrode member 37 may be adjusted with respect to the fixed position of the capillary tubes 33 so as to achieve the best spray characteristic in accordance with the potential difference between the electrode 37 and the capillary tubes 33, and other variables such as the electrical resistivity of the liquid.

Typically, the crystals 24, when squeezed slowly for five second or so, produce a potential difference of about 10 KV, and have sufficient electrical capacitance to impart at least one microcoulomb to the liquid being atomised during a five second squeeze. If the liquid output rate is about 1×10^{-4} litre per second the charge density of the atomised droplets is of the order of 2×10^{-3} coulombs per litre.

In a spray test using this specific embodiment the resultant spray exhibited satisfactory atomisation and "wrap-round" when a target tube was earthed and held at a distance of about 0·5 metre.

The pistol illustrated may readily be modified by means of a mechanical connection between the trigger 22 and a valve in the feed tube 29, so arranged that pressure of the trigger opens the valve and release closes it. In this way liquid only passes through the nozzles 33 when they are charged.

Alternative gun nozzles which may be submitted for the nozzle of Figure 2 in the gun of Figure 1 are shown in Figures 7–9.

The nozzle shown in Figures 7 and 8 comprises a hollow steel cylinder 39 having a uniform bore and a lower half of reduced external diameter. The cylinder 39 at its upper part is held by frictional engagement within the tubular distributor 7 of Figure 1 and connected via the metal wire 10 and and cable 11 to the high potential terminal of the module 3. At its lower part cylinder 39 is closed by seal 40 and has four holes 41 of capillary size extending radially of the cylinder wall.

An outer steel cylinder 42 at its upper part embraces an intermediate part of the cylinder 39 and is held by frictional engagement thereon. At its lower part cylinder 42 defines, with the lower part of cylinder 39, an annular cavity 43. The holes 41 connect the cavity 43 with the inside of cylinder 39.

Encircling the distributor 7 is the dish 12 supporting the field-intensifying ring member 13.

In use, turning the switch 4 to its "ON" position, cylinders 39 and 42 become electrically charged. Liquid passing through distributor 7 passes out of holes 41 into cavity 43 and emerges therefrom in an atomised and electrostatically charged form.

The nozzle shown in Figure 9 comprises a solid steel cylinder 44 held at its upper part by frictional engagement with the distributor 7 of Figure 1. The cylinder 44 has a central axial bore 45 running almost the length of the cylinder and terminating at a transverse bore 46 in the lower part of the cylinder. The cylinder 44 is connected to the module 3 via the metal wire 10 and cable 11. The lower part of the cylinder terminates as a solid disc 47 having a bottom surface 48.

In use, when cylinder 44 becomes electrically charged, liquid from distributor 7 passes through bores 45 and 46 and flows around disc 47 to surface 48 from which it is atomised.

If the flow rate of liquid out of bore 46 is sufficiently reduced atomisation of the liquid may occur from the surfaces adjacent the two exits of bore 46.

The embodiment shown in Figures 10 and 11 comprises the spray gun of Figure 1 fitted with a deflector electrode system to prevent "back-spray".

As shown in Figures 10 and 11 a disc 51

formed of an insulating material embraces the distributor 7 at its mid-section and is held thereon by frictional engagement. Partly embedded in the lower surface of the disc 51 is a deflector electrode 52 in the form of a steel ring. The deflector electrode 52 is connected, via a high voltage cable 53, to a tapping 54 of a potential divider 55. The divider 55 comprises a resistor of 10^{10} ohms, connected at one end to the high potential cable 11 and at its other end to the earth lead 14. The high resistance of divider 55 minimises current drain from the high voltage source 3, and serves as a current limiter in the event of a short circuit occurring at the deflector electrode 52.

In operation, with switch 4 in the "ON" position the deflector electrode 52 receives a high potential from the potential divider 55. Suitable adjustment of the tapping 54 may give any desired potential between zero volts and the potential of the source 3. A typical voltage on the deflector electrode 52 would be 14 KV.

The position of the deflector electrode 52 in relation to the field-intensifying electrode 13 and the spray nozzles 9 may be selected by moving the disc 51 along the length of the distributor 7.

Liquid emerging from the nozzles 9 is atomised and directed by the combined electric field forces set up not only by the high voltage on the nozzles 9 and the local low potential of the field-intensifying electrode 13 but also by the high potential on the deflector electrode 52.

Referring to Figures 12–14, the head of the spraying apparatus comprises a rectangular body 61 formed of an insulating plastics material and having a rectangular chamber 62. Along the length of its lower face, the body 61 has an integrally formed upstanding projection 63 having a longitudinal slit 64 which connects with chamber 62. The upper face of the body 61 has an aperture 65, adapted to receive (by means not shown) a liquid to be sprayed, and which communicates with chamber 62.

The slit 64 is divided by a conducting surface formed of a thin metal sheet 66 connected to a source of high potential (not shown). Held by supports 67 adjacent the projection 63 is an earthed metal wire 68 enclosed in a sheath 69 formed of an insulating plastics material.

In operation with the high potential applied to the metal sheet 66, liquid to be sprayed enters the chamber 62, via the aperture 65. It emerges from the slit 64 where it is atomised adjacent the metal sheet 66. The wire 68 acts as a field-intensifying electrode on both sides of the metal sheet 66. Because it has an insulated protective surface the metal wire 68 can be disposed closer to the metal sheath 66 than if it were not so insulated, and also with a greatly reduced risk of arcing.

In an alternative embodiment the conducting surface may comprise a metal wire.

In a further embodiment utilising the linear slit arrangement a multiplicity of wire or metal sheet conducting surfaces in parallel and disposed between a multiplicity of such sheathed wire field-intensifying electrode is used. Such an arrangement allows of an increase in the volume of liquid to be sprayed.

The various devices described are particularly useful in the process of the invention, that is to say, in spraying liquid pesticides. They may easily be made portable and self-contained, being conveniently powdered by low output power source such as dry cells, piezoelectric sources of photoelectric sources. The devices may readily be used for many other purposes where atomisation and deposition (e.g. paint-spraying, lacquering), or atomisation alone, are required. The process of the invention has particular advantages over known methods of spraying liquid pesticides because it can give a more even coating of pesticides on foliage. Electrostatic forces direct the spray particles to their target, reducing drift, and enable leaves to be coated on both sides. Liquid pesticidal compositions sprayed by the process of the invention may be for example insecticides, fungicides and herbicides. Typically they are in the form of solutions or dispersions of a pesticide in a pesticidally inert organic diluent (e.g. a liquid hydrocarbon) but it is also possible to spray liquid pesticides substantially undiluted. Because deposition is uniform, drift is minimised, and low flow-rates can be used, the process is particularly suitable for applying pesticides undiluted or in highly concentrated formulations (ultra-low volume spraying).

WHAT WE CLAIM IS:—

1. A process of spraying pesticides which comprises supplying a liquid pesticidal composition to an electrically conducting or semi-conducting surface adjacent a field intensifying electrode, the electrode being at such a potential and so sited relative to the surface that an atomising field strength is created at the surface so that the liquid is atomised at least preponderantly by electrostatic forces substantially without corona discharge to form electrically charged particles which are projected away from the electrode.

2. A process of spraying pesticides as claimed in Claim 1 in which the size of the particles is controlled by control of the field strength at the surface.

3. A process of spraying pesticides as claimed in Claim 2 in which the field

strength is controlled by varying the distance of the field-intensifying electrode from the surface.

4. A process as claimed in any of the previous claims in which the field-intensifying electrode is at earth potential.

5. A process as claimed in any of Claims 1 to 4 in which the liquid pesticidal composition is a solution or dispersion of a pesticide in a pesticidally inert organic diluent.

6. Electrostatic spraying apparatus suitable for use in the process of Claim 1 which comprises a spray-head having a conducting or semi conducting surface; means for electrically charging the spray-head surface to a potential of the order of 1–20 kilovolts; means for delivering spray liquid to the surface; a field-intensifying electrode mounted adjacent to the surface; and means for connecting the field-intensifying electrode to earth; the electrode being so sited relative to the surface that when the surface is charged, the electrostatic field thereat causes liquid thereon to atomise without substantial corona discharge to form electrically charged particles which are projected past the electrode.

7. Apparatus as claimed in Claim 6 in which the field-intensifying electrode is adjustably mounted on the apparatus so that the distance between the electrode and the surface can be varied, thereby varying the field strength at the surface.

8. Apparatus as claimed in Claims 6 or 7 in which the field-intensifying electrode is sited as close as possible to the surface without discharge occurring between them.

9. Apparatus as claimed in any of Claims 6 to 8 in which the field-intensifying electrode is covered with an insulating material.

10. Apparatus as claimed in any of Claims 6 to 9 in which the field-intensifying electrode is sited level with the surface.

11. Apparatus as claimed in any of Claims 6 to 9 in which the field-intensifying electrode is sited forward of the surface.

12. Apparatus as claimed in any of Claims 6 to 11 in which the surface forms at least part of one or more orifices for the emission of liquid.

13. Apparatus as claimed in Claim 12 in which the surface comprises the edges of two concentric tubes which define an annular orifice for the emission of liquid.

14. Apparatus as claimed in Claim 12 in which the surface comprises at least one or two substantially parallel edges defining a slot-shaped orifice for the emission of liquid.

15. Apparatus as claimed in any of Claims 6 to 14 which further comprises a further field adjusting member by which the spray pattern may be controlled.

16. Apparatus as claimed in any of Claims 6 to 15 which further comprises a deflector electrode operably capable of maintaining a high potential of the same sign as the atomised liquid, and so sited between the field-intensifying electrode and the body of the apparatus as to prevent "backspray".

17. Spraying apparatus as claimed in any of Claims 6 to 11 in which the conducting or semi-conducting surface to which liquid is applied is rotatable to assist atomisation of the liquid.

18. Spraying apparatus comprising at least two or more spraying devices as claimed in any of Claims 6 to 17 mounted on a boom.

19. Spraying apparatus as claimed in Claim 18 in which the boom is mounted on a powered vehicle such as a tractor or an aircraft.

20. A portable, self-contained electrostatic spray gun suitable for use in the process of Claim 1 which comprises a reservoir for containing liquid to be sprayed; a spray-head having a conducting or semi-conducting surface adjacent which liquid may atomise; means for delivering the liquid from the reservoir for atomisation adjacent to the surface; means for connecting the field-intensifying electrode to earth; and a power source adapted to charge the spray-head surface to a potential of the order of 1–20 kilovolts; the electrode being so sited relative to the surface that when the surface is charged, the electrostatic field thereat causes liquid thereon to atomise without substantial corona discharge to form a cloud of electrically charged particles which are projected past the electrode.

21. An electrostatic spray gun as claimed in Claim 20 wherein the power source is one or more dry cells.

22. An electrostatic spray gun as claimed in Claim 20 wherein the power source is piezoelectric.

23. An electrostatic spray gun as claimed in Claim 20 wherein the power source is photoelectric.

24. An electrostatic spray gun as claimed in any of Claims 20 to 23 wherein the distance of the field-intensifying electrode from the surface is variable thereby to determine and control the droplet size of the atomised liquid.

25. Electrostatic spraying apparatus constructed and arranged substantially as described herein and shown in Figures 1 to 6.

26. Electrostatic spraying apparatus constructed and arranged substantially as described herein and shown in Figures 7 to 11.

27. Electrostatic spraying apparatus constructed and arranged substantially as described herein and shown in Figures 12 to 14.

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Agent for the Applicants.

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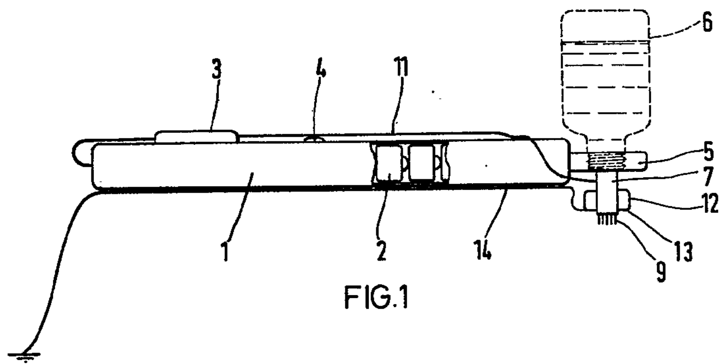

FIG.1

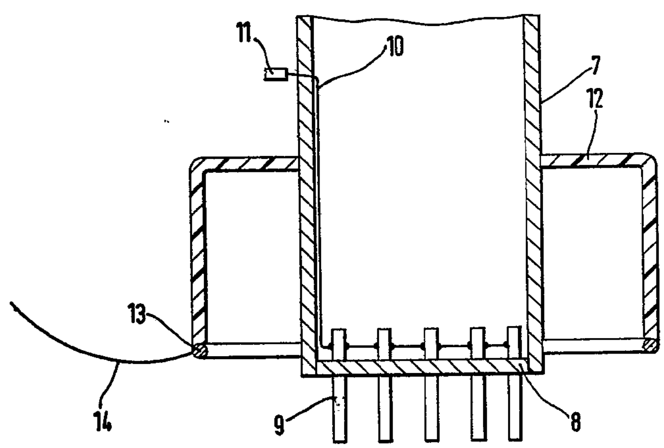

FIG. 2

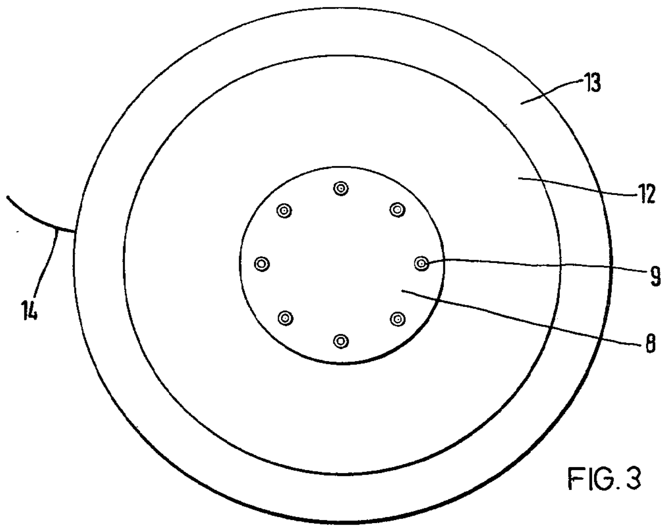

FIG. 3

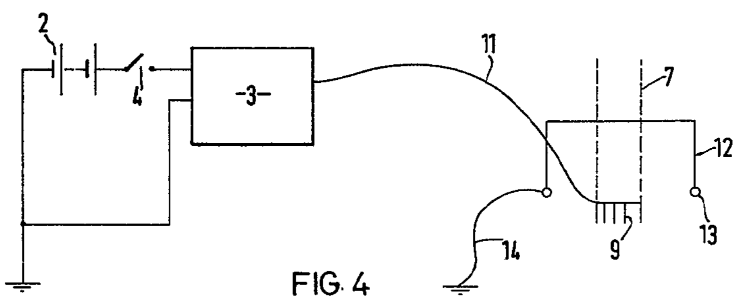

FIG. 4

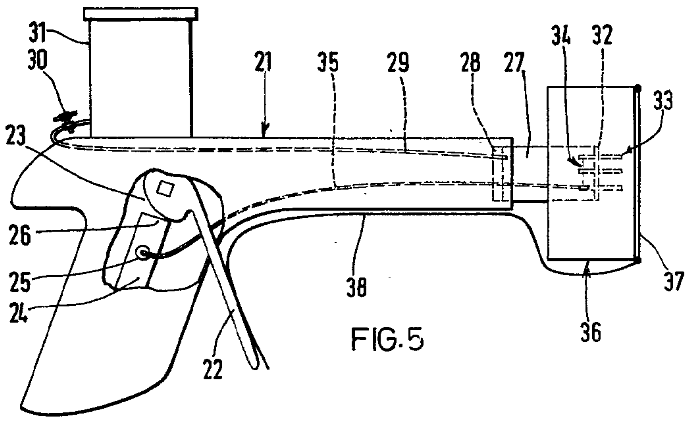
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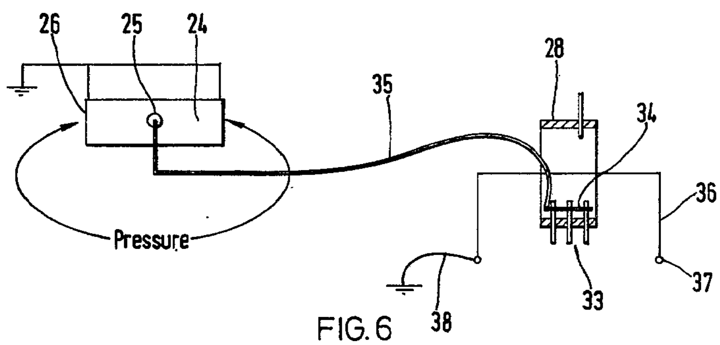
FIG.5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Pressure
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FIG.6

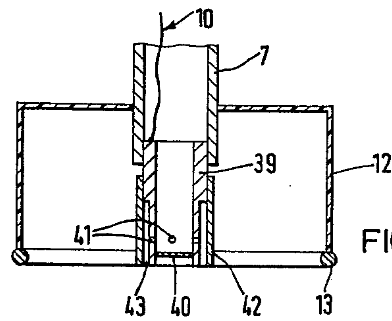
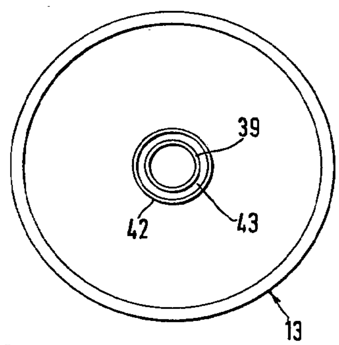


FIG. 7

FIG. 8



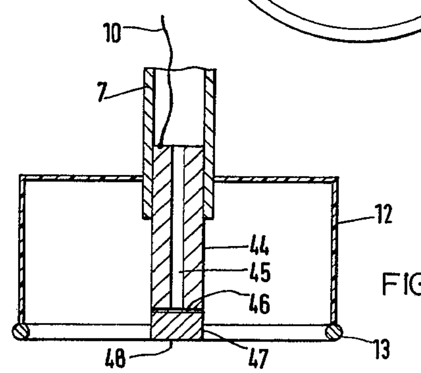


FIG. 9

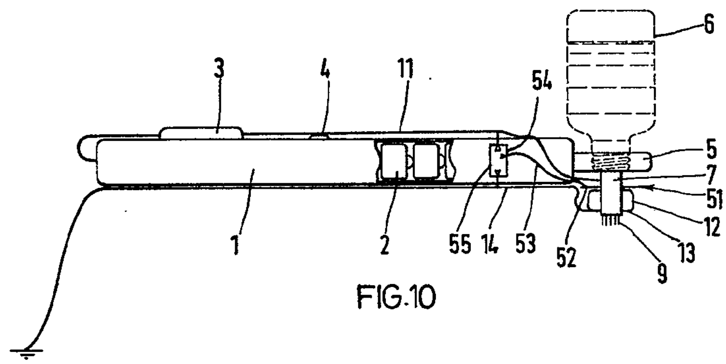


FIG.10

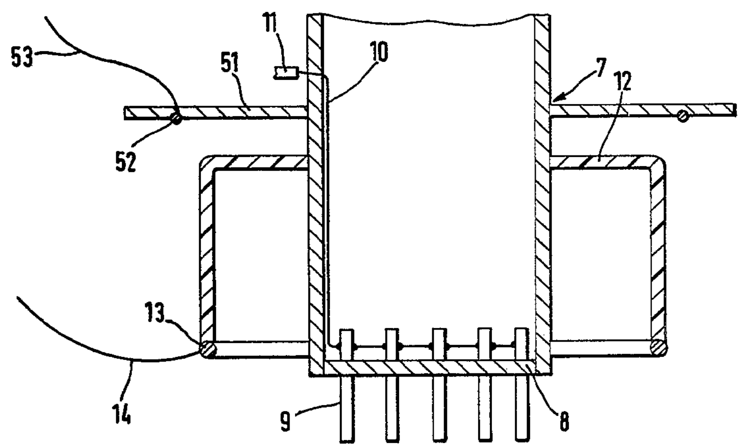


FIG.11

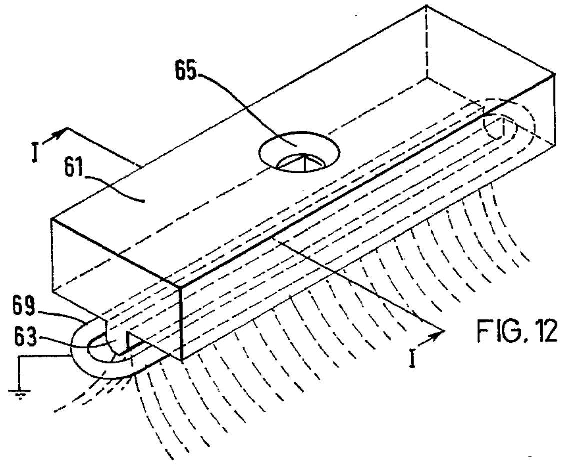


FIG. 12

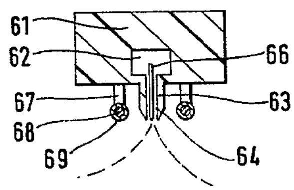


FIG. 13

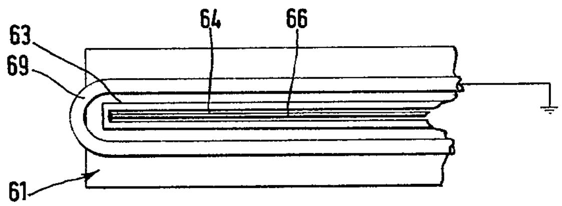


FIG. 14